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AGRICULTURAL RESEARCH ADMINISTRATION
BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

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Project Date July 19, 1948 Author

TITLE

THE CONTROL OF THE PINE REPRODUCTION WEEVIL, IN BRUSHFIELD PLANTINGS ON THE SHASTA AND LASSEN NATIONAL FORESTS, BY THE USE OF DDT SPRAYS

Season of 1947

by

Ralph C. Hall, Entomologist

Forest Insect Laboratory
29 Forestry Bldg., U. C.
Berkeley 4, California

SUBJECT—

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Forest Insect Laboratory
29 Forestry Bldg., U. C.
Berkeley 4, California

December 20, 1948

TO: F. C. Craighead, in Charge, Forest Insect Investigations

FROM: F. P. Keen, in Charge, Berkeley Laboratory

SUBJECT: Report on Control of the Pine Reproduction Weevil, by R. C. Hall

Enclosed are two copies of a detailed report by Dr. Hall on the experiments conducted in June 1947 for controlling the pine reproduction weevil in the brushfield plantations of the Shasta and Lassen National Forests. Airplane spraying of DDT was the principal control method but a fog machine and back-pack pumps were also used.

The spraying gave over 85 percent reduction in weevil populations and reduced the pine reproduction losses by fully 90 percent. The cost of the airplane spraying was only $1.11 per acre, which probably is a new record for low cost of treatment by this method. The DDT residual spray apparently gave protection for about two months' time.

On the basis of these very satisfactory experimental results, we feel that it is now possible to protect pine plantations from damage by the pine reproduction weevil during the few years when the young trees are most susceptible to attack. It should not be necessary to spray every year but only when surveys show that plantations are threatened by build-up of weevil populations.

cc: Portland Laboratory ✓
Coeur d'Alene "
Fort Collins "
Eastern Laboratories

THE CONTROL OF THE PINE REPRODUCTION WEEVIL, IN BRUSHFIELD PLANTINGS ON THE SHASTA AND LASSEN NATIONAL FORESTS, BY THE USE OF DDT SPRAYS

Season of 1947

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Ralph C. Hall, Entomologist

Hat Creek, California

July 19, 1948

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THE CONTROL OF THE PINE REPRODUCTION WEEVIL, IN BRUSHFIELD PLANTINGS ON THE SHASTA AND LASSEN NATIONAL FORESTS, BY THE USE OF DDT SPRAYS

INTRODUCTION

The pine reproduction weevil, Cylindrocopturus eatoni, is one of the most destructive insect enemies to ponderosa and Jeffrey pine when planted in brushfield areas. This insect has been responsible for the almost complete destruction of the brushfield planting in the Big Springs area on the Lassen National Forest. It has recently become established in the Big Springs and Mt. Shasta brushfield plantings and in 1946 showed evidence of widespread destruction in both of these fields.

An experimental control project on this insect was suggested to the U. S. Forest Service for the Shasta field by Patterson on April 15, 1947. The Forest Service took favorable action on this recommendation and set up a fund for an experimental control job. Following this, R. C. Hall and J. E. Patterson of the Forest Insect Laboratory made a further check of the Shasta field in cooperation with N. J. Farrell, Supervisor, and R. Wagner, Assistant Supervisor, of the Shasta National Forest, on May 2, 1947. As a result of this further check, it was determined that the serious infestation in the Shasta field was restricted to an area of about forty acres in compartment P-24-39 with very light infestation along the west fringe of Compartment P-25-40 (Fig. I). Hall also made an examination of the Burney Springs planting on the Lassen National Forest and found serious damage in Compartments P-55-37, P-67-38, and P-68-39 (Fig. II). This infestation was found to be much more serious in the northern portions of all of these compartments. No infestation was found in the west block of the Burney Springs planting. In the infested portions of both of these plantings there appeared to be a tremendous build-up of weevil damage in 1946 with indications of continuing heavy loss in 1947 unless control measures were taken. It was therefore recommended that both the Shasta and Burney fields be included in the experimental control program. The Forest Service agreed to this and a working plan was prepared by Hall on May 9 covering the proposed field program.[1]

COOPERATION AND PERSONNEL

This experimental control project was undertaken by the U. S. Forest Service in the hope of protecting their large investment in brushfield pine plantations on the Lassen and Shasta National Forests. Technical supervision of the project was handled by the Berkeley Forest Insect Laboratory of the Bureau of Entomology and Plant Quarantine. Also valuable assistance was given by the California State Division of

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[1] Entomological Working Plan for the Pine Reproduction Weevil Control Project in the Shasta and Burney Springs Brushfield Plantings - by R. C. Hall, Forest Insect Laboratory, Berkeley, Calif., May 9, 1947.

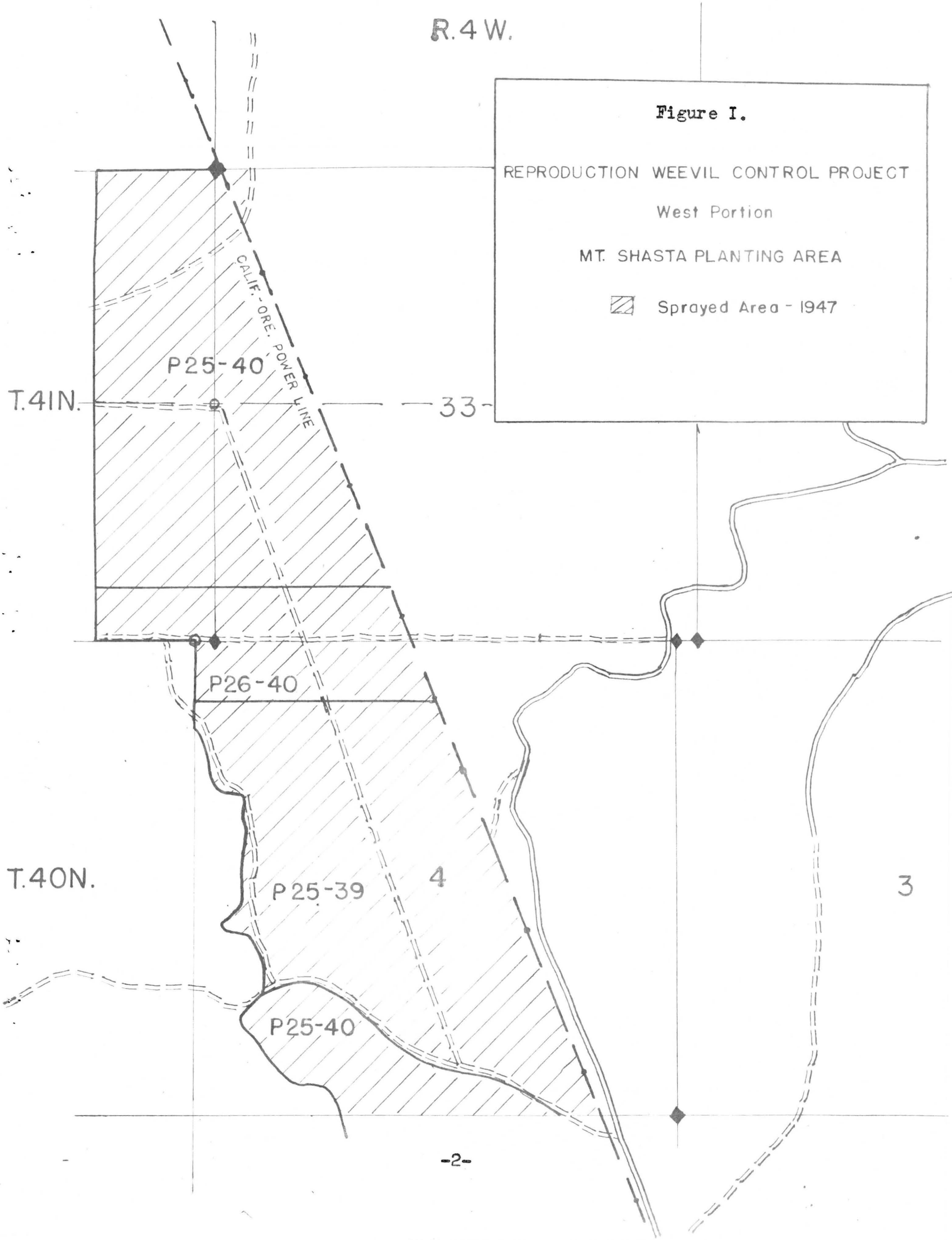

Figure I.

REPRODUCTION WEEVIL CONTROL PROJECT

West Portion

MT. SHASTA PLANTING AREA

▨ Sprayed Area - 1947

R.4W.
T.41N.
T.40N.
CALIF.-ORE. POWER LINE
P25-40
33
P26-40
P25-39
4
3
P25-40

Entomology and Plant Quarantine in loaning men and equipment, and by the University of California's Department of Entomology in analyzing spray deposits.

The U. S. Forest Service

The U. S. Forest Service allotted sufficient funds to cover the cost of spray materials (including DDT, xylene, triton, diesel), kerosene, transportation, miscellaneous caging materials, and labor for applying the spray materials, and for the setting up of sample plots for the purpose of evaluating the spray results. Part of the expense of the project was charged to the Shasta and part to the Lassen National Forests.

The California State Division of Entomology and Plant Quarantine

The California State Division of Entomology and Plant Quarantine furnished very valuable assistance in the loan of their Buffalo turbine blower and pump for mixing and loading the spray material. Mr. Hugh Wallace of this Division drove the turbine equipment from Sacramento to Hat Creek and spent several days in the field assisting with the application of the sprays. Other members of the Division offered many helpful suggestions on formulae and spray technique.

The University of California

Professor W. M. Hoskins in charge of Insect Toxicology of the University of California furnished very valuable suggestions and assistance in the determination of spray deposits. Also Mr. P. S. Messenger, research assistant in Insect Toxicology, assisted in the making of chemical analyses of DDT deposits.

The Forest Insect Laboratory

Dr. Ralph C. Hall was designated as project supervisor for this experimental control job. He was very ably assisted on this project by Jack W. Bongberg and Albert S. Perry. Bongberg was responsible for the setting up of the sample plots for the purpose of evaluating the spray results, and also assisted with the aerial spray application. Perry was responsible for determining the distribution of the spray, the droplet size, the rate of application, and the residual effect for the season following the application. The Laboratory staff was responsible for the supervision of the various entomological requirements as outlined in the Work Plan of May 9.

CONTROL OBJECTIVES

The general objectives of this experimental control job were two-fold.

The first objective was to kill as many of the weevils as possible, when they had emerged and prior to the time when they had started to oviposit, through a contact spray at the time of application.

The second objective was to give protection to the uninfested trees through a residual effect of DDT which would remain on the foliage for several weeks following the spray application. Although very little was known about the effect of DDT on this particular insect, it was expected that the deposit would prevent successful attack by the weevil.

TIMING OF THE SPRAY APPLICATION

The timing of the spray application was set to coincide with the period of peak emergence and prior to the time when any oviposition was expected. It was originally planned to spray the Shasta field on June 2 and the Burney Springs field a few days later. A prolonged period of rainy weather late in May retarded emergence and the spray date for the Shasta field was finally set for June 17 and the Burney Springs field following that.

METHOD OF TREATMENT

Prior to this control job there had been practically no work done on the effectiveness of DDT in controlling the pine reproduction weevil so it was necessary to test out various formulae, with different rates of application and different machines for their application.

Formulae

The various formulae used in this experiment were those which had proven effective in controlling other forest and agricultural crop insects. A list of these formulae are presented in Table 1.

Equipment

The plantings in both of the brushfields were made in bulldozed strips which were constructed about a rod apart through the dense brush. Prior to planting there was a cleared strip several feet in width made when the stripping was done. In practically all cases, these cleared strips had grown over with a dense cover of new brush which made them very difficult to navigate. This factor limited the choice of equipment to three types. These were the airplane, the Buffalo turbine blower mounted on a weapons carrier, and the hand back-pack sprayer. The first two types of equipment had been used with very good success in controlling forest defoliators and were expected to have promise on the brushfield problem. It was planned to try out the Hi-Fog Gun, which had proved quite successful in spraying *Ribes* and wild grape under forest conditions but it was impossible to get one of these machines in time for the test.

1. Aircraft

The job of airplane spraying was let on a contract basis to the Interstate Commercial Flyers, Inc., of the Davis-Winters Flight Strip. Their aircraft consisted of an N3N Navy Training plane converted for spraying.

Table 1.--Formulae Used in Shasta and Burney Springs Fields

Formula A	1 lb. DDT 2 pts. xylene 6 pts. Diesel oil
" B	1 lb. DDT 2 pts. xylene 6 pts. kerosene
" C	1 lb. DDT 3 pts. xylene 2.5 oz. Triton 12.6 pts. water
" D	1 lb. DDT 2 pts. xylene 14 pts. Diesel oil
" E	1 lb. DDT 2 pts. xylene 14 pts. kerosene

(Figs. III and IV). The forward cockpit was removed and replaced by a spray tank with a capacity of 106 gallons. The spray was agitated in the tank by an air-driven pump when the plane was not discharging spray.

A. Spray Apparatus - A boom extended the full length of the lower wing (30 feet) with 28 whirl-spray nozzles having 1/8-inch orifice operating at 40 pounds pressure per square inch. The pump operated at 1,800 r.p.m. and delivered 80 pounds pressure per square inch. Each nozzle was equipped with an individual shut-off valve. The pump for agitation was a cylindrical air-driven type cast of aluminum.

B. Flight data - The indicated air speed was 80 miles per hour. The course in relation to the wind was 30 degrees tail wind to left of line of flight. Altitude of flight was from 20 to 30 feet above the level of the brush.

2. Turbine Blower

The turbine blower was the Buffalo mounted on a weapons carrier, and loaned for this experiment by the California State Division of Entomology and Plant Quarantine. This was equipped with a 50-gallon tank with both a round and fishtail nozzle which was capable of being swung in an arc of about 190 degrees at right angles to the truck body (Fig. V).

3. Hand Back-Pack Sprayers

The back-pack sprayers were the Hudson and Brown makes, of 2½ gallons capacity.

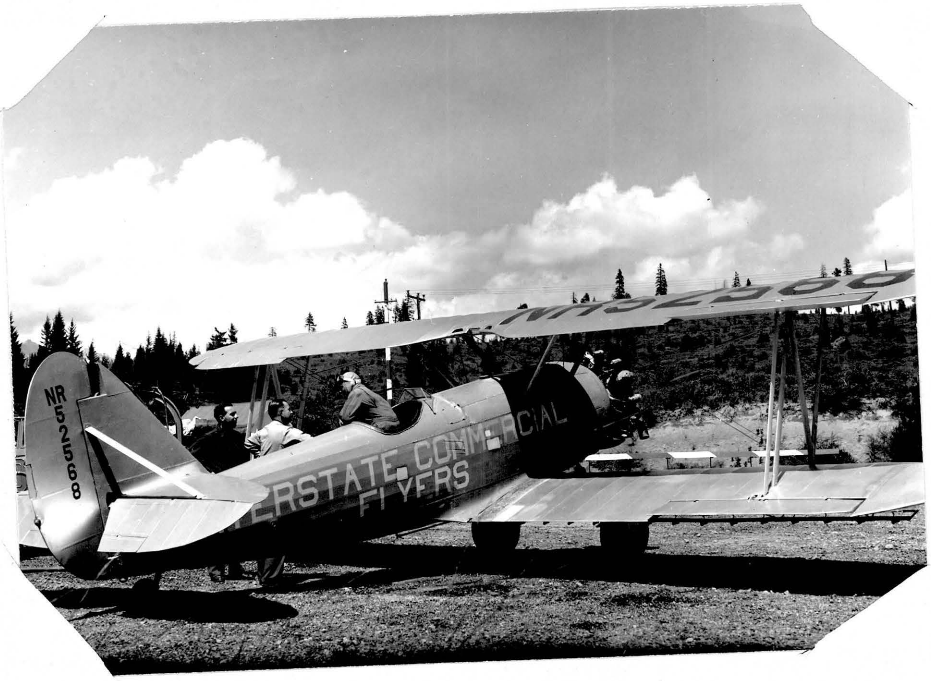

Figure III.--The N3N Navy Training Plane, converted for spraying, at the airport at Mt. Shasta ready to take on a load of spray. The forward cockpit was removed and replaced by a spray tank with a capacity of 106 gallons. The spray was agitated by an air-driven pump when the plane was not discharging spray. Note the spray boom extending the full length underneath the wing. This boom was equipped with 28 whirl-spray nozzles having 1/8-inch orifice operating at 40 pounds pressure per square inch.

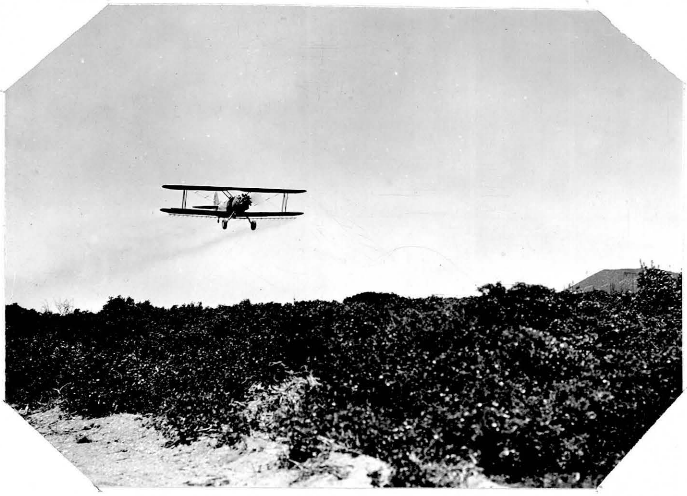

Figure IV.--Airplane in flight dispersing spray over the Mt. Shasta brushfield. The plane flew at about 20 feet above the general level of the brush and applied the spray in swaths of about 100 feet in width. Note the heavy brush cover in which the pine trees were growing.

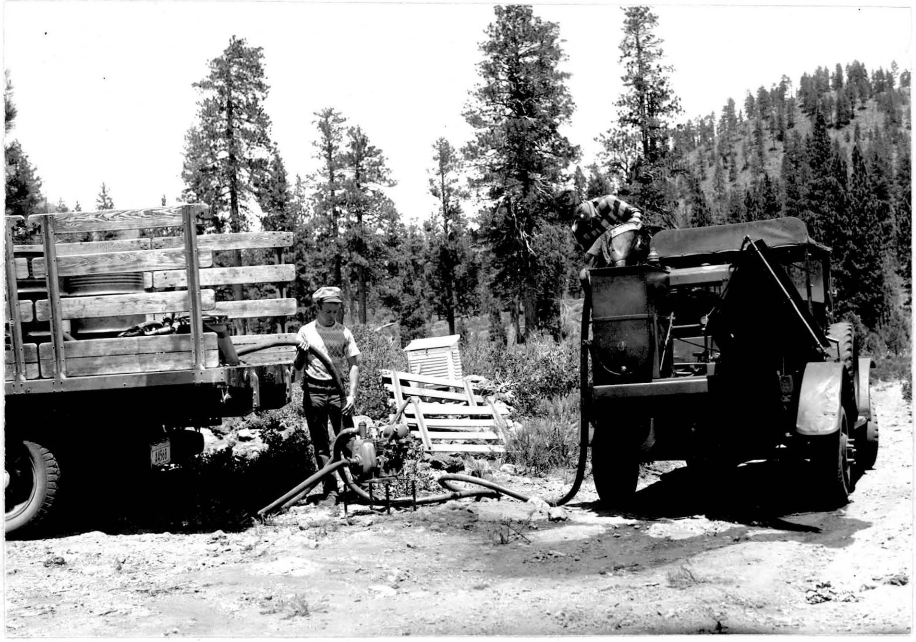

Figure V.--The turbine blower, with fishtail nozzle, mounted on the back of a weapons carrier. A load of spray is being loaded into the rig from ready-mixed material on the stake side truck. Weather shelter in the background housed the weather instruments to check temperature and humidity during the spray program. This machine was loaned by the California State Division of Entomology and Plant Quarantine for this experimental control job.

4. Mixing and Loading Rigs

The Interstate Commercial Flyers, Inc., had a special mixing tank capable of mixing 106 gallons at a batch (Fig. VI). This machine also loaded the plane. The California State Division of Entomology and Plant Quarantine loaned one of their small portable pumps for mixing the spray for the turbine application (Fig. VII).

AREAS TREATED

Shasta Brushfield

This plantation covers approximately 2,500 acres on the west slope of Mt. Shasta, east and north of the city of Mt. Shasta, at an average elevation of about 4,000 feet. The area treated in this field covered about 625 acres in Compartments P-24-39, P-26-40, and P-25-40 (Fig. I). This area was bounded on the east by a high tension line and on the west by a fringe of timber. Practically all of the infestation in this field was confined to about 400 acres in P-24-39.

Practically all of this area was treated by airplane, except for a small wedge-shaped piece in the southwest corner of Compartment P-24-39 where a fringe of pole-sized trees made it impractical to cover with the plane.

1. Airplane

About 500 acres were treated by airplane with Formula A at the rate of 1 pound of DDT per acre. About 125 acres were treated at the rate of 2 pounds of DDT per acre with the same formula. In the case of the double dose, the area was covered twice with 1 pound per acre dosage (Table 2.) The spray was applied by the plane flying at an elevation of about 20 to 30 feet above the general level of the brush, at approximately 80 miles per hour. The plane carried a load of 50 gallons of spray which was applied in swaths of about 100 feet for each flight. The airport was located south of the city of Mt. Shasta about 8½ miles from the north edge of the treated field (Fig. I). The change in elevation from the airport to the highest point in the brushfield was about 1,200 feet. Wind movement during the period of spray application varied from about 5 miles per hour at the start to about 15 miles per hour at the finish. The pilot did an excellent job of flying and was very consistent in maintaining a uniform height above the brush and in flying strips one hundred feet apart. His plane practically always centered over the flag men at the center and end of the field. The first load was off at 10:05 a.m. on June 17 and the last load was dispersed at 5:20 p.m. Thirteen loads of 50 gallons each were dispersed during this time for a total gallonage of 650 (Table 3).

2. Hand Back-Pack Sprayers

About 12 acres were treated by hand with back-pack sprayers, using the same formulae as that by plane. In this case, however, the dosage per tree was much heavier because it was still applied on the basis of one pound per acre but all of the spray was concentrated on the pines. In the case of the plane, the dispersal was area-wide and most of the spray actually covered brush.

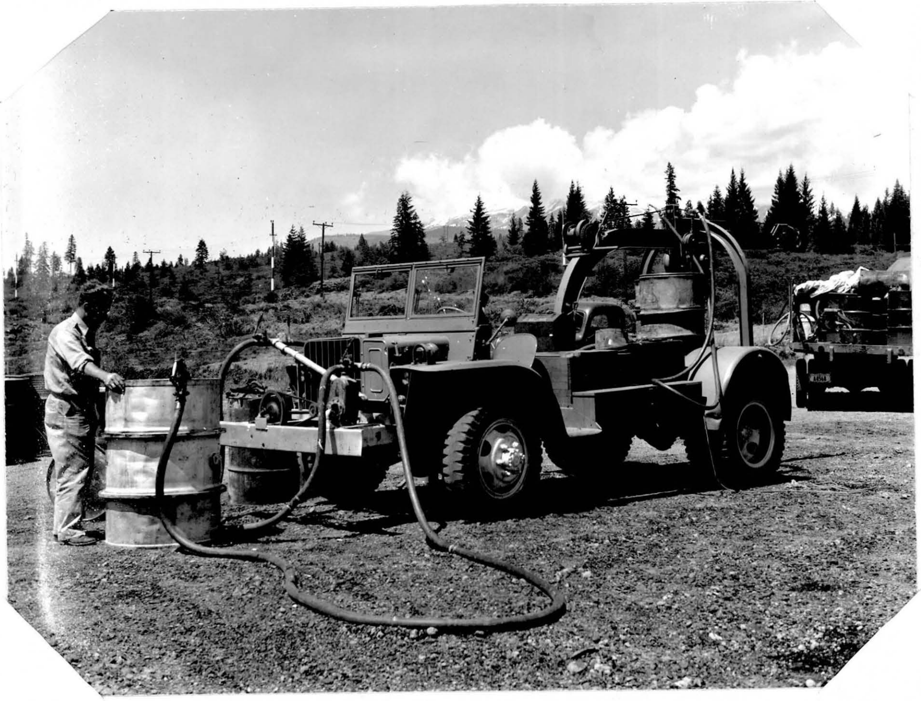

Figure VI.--Mixing and loading rig for the plane at the Mt. Shasta airport. This machine was furnished by the Interstate Commercial Flyers Company as part of the job. The mixing tank had a capacity of 110 gallons. After the spray was thoroughly mixed, it was pumped into the spray tank on the plane. The job of loading the plane usually took about three minutes.

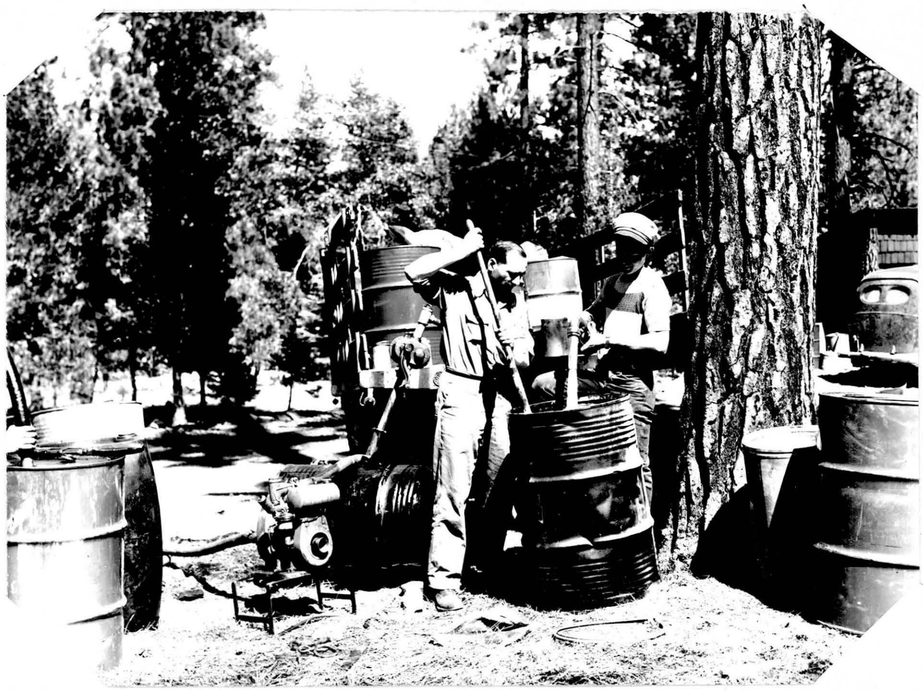

Figure VII.--Mixing the DDT spray for use in the turbine blower. The small pump at the left was loaned by the California State Division of Entomology and Plant Quarantine. The spray material was circulated through the pump for about ten minutes until it was thoroughly mixed.

Table 2.--Spray Treatment by Compartments - Shasta Field

Formula	Compartment	Rate Appl. (Lbs. DDT per acre)	Method	Foliage Injury	Acres
A	P-24-39 P-26-40 P-25-40	1	Airplane	None	500
A	P-24-39 P-26-40 P-25-40	2	Airplane	None	125
A	P-24-39 SW-corner	1	Back-Pack (Hand)	Medium	12

Table 3.--Flight Time on Pine Weevil Spray on Mt. Shasta Project

First load off at	10:05	
on at	11:52	
	1:47	
Four loads out less :15 ground time	:15	
	1:32	1:32
Off at	13:05	
On at	15:07	
Five loads less	2:02	
:20 ground time	:20	
	1:42	1:42
Off at	15:31	
On at	17:20	
	1:49	
Four loads less :15 ground time	:15	
	1:34	1:34
Total time on job		4:48
Total gallons dispersed		650

Burney Springs Brushfield

This plantation is in two main blocks south of Burney Mountain on the Hat Creek District of the Lassen National Forest. The west block of about 1,700 acres had no known infestation and was not included in the control program. The east block of about 1,300 acres had infestation in Compartments P-55-37, P-59-38, P-69-39, and P-67-38. The most serious infestation occurred in Compartment P-55-37 and it was in this area that most of the control was attempted in this plantation.

Two types of machines and various formulae were used in this field. The machines used were the Buffalo turbine and back-pack hand sprayer.

1. Turbine Blower

A total of about 109 acres was treated by this machine in the Burney Springs field. This included 65 acres treated with Formula D, 23 acres with Formula C, and 21 acres with Formula E. It was originally planned to treat a much larger acreage with the turbine but it was found that this machine could not manipulate the rows of brush without the danger of injuring the weapons carrier from large rocks hidden by the brush. For this reason, the treatment was limited to strips along existing roads which greatly reduced the area possible of treatment.

2. Hand Back-Pack Sprayers

About 50 acres were treated by hand through the use of hand back-pack sprayers. This included 12.7 acres of Formula A at the rate of 1 pound of DDT per acre; 4.4 acres of Formula A at the rate of 2 pounds of DDT per acre; 4.4 acres with Formula B at the rate of 1 pound of DDT per acre; 4.5 acres with Formula B at the rate of 2 pounds of DDT per acre; 19.1 acres with Formula C at the rate of 1 pound of DDT per acre; and 4.5 acres with Formula C at the rate of 2 pounds of DDT per acre. In all of the hand applications, the spray was applied at the rate of 1 or 2 pounds to the pine trees on each acre (Table 4). This was very much heavier than the application by means of the turbine, because the latter was on an area-wide basis and most of the spray was deposited on the brush between the pine trees.

CHECKING THE DISTRIBUTION OF THE SPRAY

The distribution of the spray applied from the airplane and the turbine blower was checked through a series of glass plates 3"x2", microscope slides provided with troughs 3/4" in diameter and 1/4" deep for collecting spray droplets, and filter paper 4 inches in diameter. These troughs were filled with a solution of 1 part of triethanolamine, 1 part oleic acid, 4 parts glycerine, and 4 parts water. These samples were placed on stands 3 feet above ground, or just above the cover of the brush, and were spaced 30 feet apart in rows of three to cover the normal swath of the airplane, and at intervals of about 50 feet apart up to 200 feet for the turbine blower.

Table 4.--Spray Treatment by Rows and Compartments - Burney Springs

No. Exp.	Formula	Compartment	Row or Area	Rate Appl. (lbs. DDT per Acre)	Method	Acres Treated
1	A	P-55-37	523-531	1	Back-Pack (Hand)	9.7
2	B	P-55-37	519-522	1	"	4.4
3	C	P-55-37	514-518	1	"	5.5
4	A	P-55-37	510-513	2	"	4.4
5	B	P-55-37	505-509	2	"	4.5
6	C	P-55-37	500-504	2	"	4.5
7	C	P-55-37	492-499	1	"	10.1
8	D	P-55-37	1-150 West	1	Turbine Blower	15.0
9	D	P-55-37	South Strip E. North Road	1	" "	25.0
10	C	P-55-37 P-59-38 P-67-38	South Strip W. North Road	1	" "	23.0
11	E	P-69-39 P-70-39	East Strip S. East Road	1	" "	21.0
12	A	P-55-37	1-75 East	1	Back-Pack (Hand)	3.0
13	C	P-55-37	76-150 East	1	"	3.5
14	D	P-69-39	South Strip E. South Road	1	Turbine Blower	25.0

The density of deposit was made on the basis of the amount of dye deposited on each filter paper. The dye was extracted with 10 cc. of xylene-kerosene mixture and measured against standard dye solutions with the Dubosq colorimeter. A second method of density of deposit was made from the deposit collected on the glass plates and analyzed according to the Hoskins method. Data on droplet size was obtained by microscopic counting and measuring 400-500 droplets in each sample.

METHOD OF EVALUATING CONTROL RESULTS

There were three principal methods used in evaluating control results. The first was a comparison of population densities prior to and following the application of the spray in the treated and check areas, and the trend of population density during the season of oviposition. The second method was the testing of the sprayed trees for residual effect of DDT throughout the season following the application of the spray. The third method was the comparison of the number of trees killed the year preceding the spray and those killed the year after the application of the spray.

Population Density

Population density prior to and following the application of spray was arrived at from two different angles. The first was through the use of paper cone collars (Fig. VIII), attached to sample living trees scattered at random throughout the field under treatment and also in the check area where no control was attempted. Prior to treatment these trees were examined and all weevils, falling into the cone when the tree was shaken, were counted. After treatment the cones were examined at daily intervals for two weeks, and all dead and live weevils were counted. Population density was also obtained by sweeping or beating methods. It was found that the most satisfactory method of collecting weevils in a net was to bend the tree over and place the top portion inside the net and then hit the tree a sharp blow. This usually dislodged all living weevils at one stroke.

Residual Effect of DDT

The residual effect of DDT following spraying was obtained through the collection of twigs from sprayed trees, and placing these in a jar of water enclosed in a cheesecloth cage (Fig. IX). Twenty-five weevils, freshly collected from the check area at Burney Springs, were introduced into each cage and mortality counts were taken at 24-hour intervals for a period of 72 hours. A series of unsprayed checks were always used as a basis of comparison for the sprayed samples. These experiments continued over a period of about two months following the application of the spray with samples taken about biweekly. The results of the forced feeding tests were also compared with the results obtained out in the field from collections made in the cones attached to the living trees.

Effect of DDT in Reducing Loss

In order to appraise the effectiveness of the spraying work in reducing loss, it was necessary to have detailed records of the number and distribution

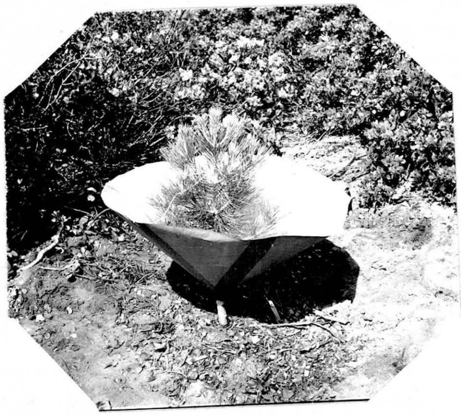

Figure VIII.--Paper cone collars constructed around sample trees for the purpose of sampling weevil populations prior to and after spraying. During periods of sampling, the tree was shaken and the weevils fell to the bottom of the cone where they were counted. Counts were also maintained on the number of dead weevils found in the bottom of the collars at the time of sampling.

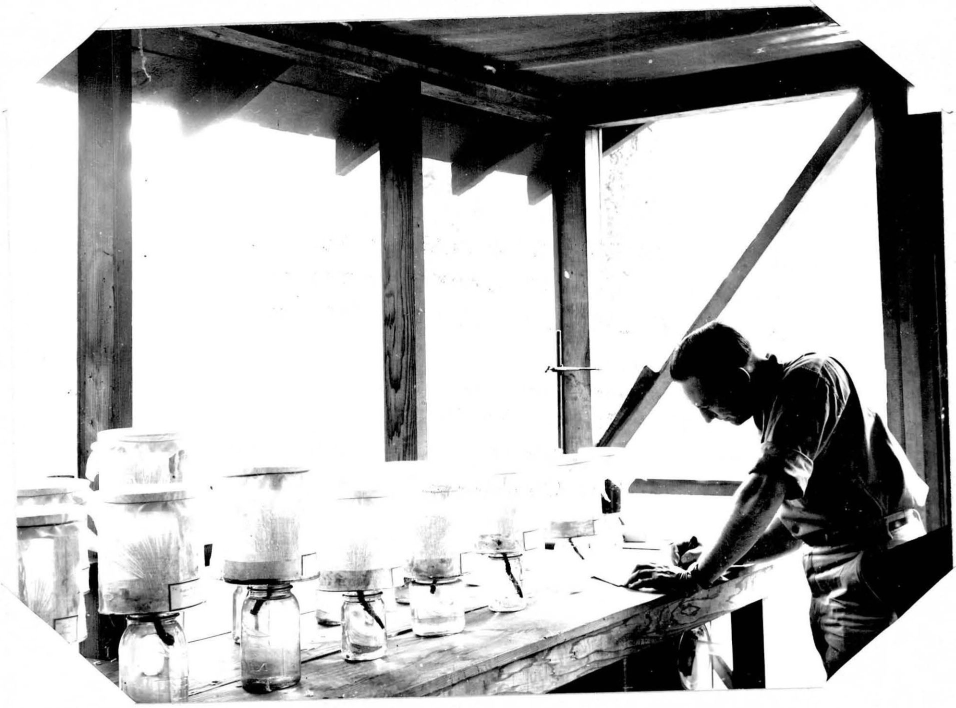

Figure IX.--Testing for residual effect of DDT. Fresh twigs were collected from various parts of both fields, sampling the different formulae and dosages at about two-week intervals. They were then placed in these cages with the cut end in a jar of water, and 25 freshly collected weevils were introduced into each cage and counts were then maintained on the number which were affected by the spray for a period of two days. Twigs from unsprayed trees were always used as a check.

of the green and killed trees, both before and after treatment. A series of sample plots or rows were established in both the Shasta and Burney Springs fields. Approximately twenty percent of the area most seriously infested in the Shasta field, and ten percent in the Burney Springs field were established on a permanent basis, of numbered rows, and numbered trees in each row. Each row which was to be used for these sample plots was numbered and staked or marked by tags at each end. Records were kept of the number, height, and condition of each tree in each row sampled. The first, last, and every tenth tree were numbered with a circular paper tag showing the tree number and row number. The following information was collected for each tree: number in the row, species, height to the nearest foot, data on condition whether killed and year of kill if possible, damage from rabbits, and whether the tree was overtopped by brush or out in the open. These sample plots were established prior to treatment and were reexamined in the late spring of 1948. It was originally planned to make this examination in the late fall of 1947 but it was found that many of the trees infested by the weevil had shown no indication of fade at that time and this work was therefore postponed until the following spring.

CONTROL RESULTS

A. S. Perry has already reported on the results of the distribution of the spray, particle size, and residual effect of DDT through the caging of sprayed twigs with live beetles and that phase will not be covered in this report.[2] The phases covered in this report will be those of population reduction, residual effect under field conditions, and reduction in loss brought about by the action of the spray.

Population Reduction

There was a marked reduction in population of adult weevils in both the Shasta and Burney Springs field almost immediately following spraying. It was apparent, from the observation of the cone cages in the Shasta field the day following spraying, that there had been a marked initial kill of the adults which were working in the field at the time of the spraying. The average population of weevils per tree, as determined from a count of the cone cages the day prior to spraying, was 31 weevils. This had dropped to 3.8 live weevils per tree at the end of the first week after spraying and dropped still further to about 1.1 live weevils per tree two weeks after spraying (Table 5.). This low level of about 1 weevil per tree was maintained throughout the balance of the season of activity. Through the cooperation of the University of California Summer School in Entomology, a test was conducted on the adequacy of the cones as a measure of population in comparison with the beating

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2/ Field Assessment of DDT/Oil Contamination Density for the Control of the Pine Reproduction Weevil (Part 1); and Bio-Assay of the Residual Effect of DDT for the Control of the Pine Reproduction Weevil (Part 2) - by Albert S. Perry. Berkeley Forest Insect Laboratory Report. September 18, 1947.

Table 5.--Observations on Living and Dead Beetles in 13 Cones in the Shasta Brushfield Plantation one Day Prior and Two Weeks Subsequent to Spraying

	June 16	June 17-24	June 24-30
Average No. Live Weevils per Tree	31	3.8	1.1
Average No. Dead Weevils per Tree	0	10.0	8.7
Total Average No. Weevils per Tree	31	13.8	9.8
Percent Killed	0	72.4	88.7

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method. Table 6 presents the results of this test. From this it appeared that the cones gave us about the same population density as did the beating method. In this test, about 250 trees were sampled by beating. The average number of weevils per tree by the beating method was 0.8 and by the cones it was 1.1 weevils per tree.

A similar test was run in the Burney Springs field. There was considerable variation between the two methods in individual treatments but for the series as a whole the two methods showed very close agreement with an average of 2.0 beetles per tree for all treatments the second week following treatment. The average population per tree on the check area where no spray had been applied was 85.5 weevils per tree for the two check cones and 51.9 weevils per tree for 16 trees sampled by beating or an average of 55.7 beetles per tree for both methods in the check area (Table 7.). It was found through repeated sampling throughout the season that the population level of weevils remained at about 2 per tree in all of the treated areas and stayed at about 50 per tree in the check area until about August 15 when it dropped to about 20.

One significant factor which was found in the population sampling was that the weevils never did build back up in the treated areas although there were heavy populations in check areas only a few rows apart in some instances. Perry[2] showed in his tests on residual effects that there appeared to be a favorable residual effect for almost two months following the application of the spray, and the field tests on population counts appear to confirm this.

Reduction in Loss

There was a very satisfactory reduction in loss in both the Shasta and the Burney Springs fields. This will be discussed below on the basis of different fields, different methods, and formulae.

Table 6.--Population Sample of Pine Reproduction Weevil in Shasta Brushfield Planting Following Treatment with DDT

Spray applied June 17, 1947.

Sampling on June 30, 1947.

Treatment	Area	Method of Collection	No. Trees Sampled	No. Live Weevils	No. Live Weevils per Tree
Hand Diesel	A	Beating	42	15	0.4
		Cones	9	11	1.2
		Both	51	26	0.5
Plane Diesel	B	Beating	60	64	1.1
		Cones	7	8	1.1
		Both	67	72	1.1
	A & B	Beating	102	79	.8
		Cones	16	19	1.2
		Both	118	98	.8
Plane Diesel	C	Beating	27	0	0
Plane Diesel	D	Beating	24	0	0

Area A. Very heavy infestation in 1946. Sprayed by hand with Diesel.

Area B. Very heavy infestation in 1946. Sprayed by plane with Diesel.

Area C. Very light to no infestation, isolation zone. Sprayed by plane with Diesel.

Area D. No known infestation. Area not sprayed.

Population counts from 13 cones on June 16 prior to the application showed an average of 31 live weevils per tree.

There is no check area unsprayed where any known infestation exists.

Table 7.--Population Sample of Pine Reproduction Weevil in Burney Springs Brushfield Following Treatment with DDT

(Sample collected on July 2, 1947)

Treatment	Row or Area	Method of Collection	No. Trees Sampled	No. Live Weevils	Ave. No. Live Weevils per Tree
Hand-Diesel	1-75-E	Beating	10	0	0
		Cone	5	2	0.4
		Both	15	2	0.1
Hand-Diesel	523-531	Beating	4	4	1.0
		Cone	1	0	0
		Both	5	4	0.9
Hand-Water	76-150-E	Beating	4	2	0.5
		Cone	1	2	2.0
		Both	5	4	0.9
Hand-Water	514-518	Beating	5	0	0
		Cone	1	5	5.0
		Both	6	5	0.8
Hand-Kerosene	519-522	Beating	4	8	2.0
		Cone	1	0	0
		Both	5	8	1.9
Turbine-Diesel	1-150-W	Beating	10	1	0.1
		Cone	1	6	6.0
		Both	11	7	0.6
Turbine-Diesel	South Strip E-North Road	Beating	5	18	3.9
		Cone	5	15	3.0
		Both	10	33	3.3
Turbine-Water	South Strip W-North Road	Beating	6	62	10.3
		Cone	None		
		Both	6	62	10.3
Check	401-491	Beating	16	831	51.9
		Cone	2	171	85.5
		Both	18	1,002	55.7
All Treatments		Beating	48	93	2.0
		Cones	15	30	2.0
		Both	63	123	2.0

1. Shasta Field

As was pointed out in the discussion on treatments, only one formula was used in the Shasta field. This was formula A, applied by the airplane at the rate of 1 pound of DDT on about 500 acres, and two pounds of DDT on 125 acres. The same formula was applied by hand by the back-pack sprayers on about 12 acres.

A. Airplane Application - The airplane application of DDT in the double dose was in three separate long strips two hundred feet in width. So far as our test can show, there was no consistent difference in the single and double doses. This is probably due to drift effects and it was very difficult to be sure just where the double dose started and stopped. It would have been preferable to have designed this test so that a single solid block had been so treated. For this reason, both treatments have been grouped together and the results are presented in Table 8. From these data it appears that there was an average reduction in loss of about 92 percent for all of the sample rows with individual variations from 76.8 percent to 94.1 percent. Four hundred and eighty trees were killed by the weevil in 1946 and this was reduced to thirty-nine in 1947. In the case of the airplane application there was no visible effect on the foliage as was apparent from the hand-applied tests.

B. Hand Back-Pack Spray Application - The hand application of Formula A appeared to give slightly better control results in an average reduction of 95 percent for this test. However, this slight superiority in control effect was more than offset by the damage to the foliage by the spray which was applied by hand. The average injury was moderate with several trees killed outright by the spray material (Table 8.). The range in reduction in loss, by rows, was from 81.8 percent to 100 percent.

2. Burney Springs Field

As was pointed out under treatment, various formulae and two types of machines were used in this field. These will be discussed below.

A. Turbine Blower - In experiment 8, using Formula D on 15 acres, the reduction in loss in 1947 was 95.8 percent. In experiment 9, using Formula D again, the reduction in loss was 94.4 percent. In experiment 14, again using Formula D, the reduction in loss was 100 percent. It should be pointed out in this latter case that there had been very light loss in this portion of the compartment in 1946 and this can not be considered as reliable a test as the first two. In experiment 10, using Formula C on 23 acres, the reduction in loss was 95.1 percent. In experiment 11, using Formula E, the reduction in loss was 100 percent but, as in the case of experiment 14, the loss was so low in 1946 that this cannot be considered as significant. In all cases with the turbine blower it appears that satisfactory control was accomplished. In the case of the turbine blower, it was assumed that the width of the control

Table 8.--Spray Treatment in Shasta Brushfield

Results of Sample Plot Checks

Compartment P-24-39

Sample Rows	96-101-06	111-16-21	126-31-36	141-46-51	156-61-66	171-76-81	186-91-96-201	All Rows
	Number of Trees							
	Formula A - Airplane Application							
Living	152	312	267	158	140	187	145	1,361
Killed 1945	5	2	10	17	21	0	3	58
Killed 1946	14	27	122	141	128	17	31	480
Killed 1947	3	2	10	9	10	1	4	39
Total	174	343	409	325	299	205	183	1,938
Reduction in Loss %	78.6	92.6	91.8	93.6	92.2	94.1	87.1	91.9
	Formula A - Back-pack - Hand							
Living	21	50	40	21	31	33	28	224
Killed 1945	0	0	1	0	3	0	1	5
Killed 1946	5	2	9	37	23	13	11	100
Killed 1947	0	0	0	1	0	2	2	5
Total	26	52	50	59	57	48	42	334
Reduction in Loss %	100	100	100	97.3	100	84.6	81.8	95.0

strip was approximately 4 chains except in the case of experiment 8 where it was believed that the coverage was only about 2 chains due to an adverse wind. It appeared in many cases that the control effects extended for greater distances than the assumed 4 chains. This was particularly true of experiment 9 where it appeared that there was a definite control effect out as far as 500 feet from the position of the blower (Tables 4 and 9).

In all of the experiments with the turbine blower there was no visible injury to the pine foliage. In the combined tests with the turbine blower on all areas treated, the number of trees killed by the weevil in 1946 was 209. The spray applied to these areas in 1947 apparently reduced the number of trees killed to 10 or an average reduction in loss of 95.2 percent.

B. Hand Back-pack Spray - Approximately 50 acres were treated with the hand back-pack sprayer in the Burney Springs field. In experiment 1, using a formula at the rate of 1 pound of DDT per acre, the number of trees killed in 1947 was 1 compared to 103 killed on the same area the previous year in 1946. This resulted in a reduction in loss of 99.0 percent. This formula, however, caused severe burning to the pine foliage. In experiment 12, using the same formula and rate of application, the loss of trees in 1947 was one compared to 58 the previous year. This resulted in a reduction in loss of 98.2 percent. Foliage damage in this experiment was moderate. In experiment 4, the same formula was used at the rate of 2 pounds of DDT per acre. There was one tree killed in 1947 on the area of sample compared to 98 the previous year or a reduction in loss of 98.9 percent. Foliage damage with this double dosage was very severe and many trees were killed by the spray. In all cases, with Formula A mixed in diesel fuel, there was some damage to foliage.

In experiment 2, using Formula B, there were two trees killed by the weevil in 1947 compared to 24 killed the previous year, or a reduction in loss of 91.6%. Damage to the foliage was moderate. In experiment 5, using this same formula at the rate of 2 pounds of DDT per acre, there were no trees killed in 1947 compared to 108 killed the previous year, or a reduction in loss of 100 percent. The foliage damage in this case was severe with some trees killed. Although there was some damage to the foliage from Formula B mixed in kerosene, it was quite evident that this lighter oil caused less damage than the heavier diesel fuel.

In experiment 3, using Formula C at the rate of one pound of DDT per acre, there were three trees killed by the weevil in 1947 compared to 125 the previous year, or a reduction in loss of 97.6 percent. In experiment 13, using the same formula and same rate, the number of trees killed in 1947 was two compared to fifteen killed the previous year, or a reduction in loss of 86.7 percent. In both of these tests, there was no visible damage to pine foliage. In experiment 7, using Formula C at the same rate per acre, there were two trees killed in 1947 compared to 74 in 1946 or a reduction in loss of 97.3 percent. In experiment 6,

Table 9.--Spray Treatment in Burney Springs Field

Results of Sample Plot Checks

	Exp. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
	Formula	A	B	C	A2	B2	C2	C	D W	D N	C N	E	A	C	D	All Treatments
	Sample Row	526	520	516	510	506	501	498	5-145	400-91	750	800	5-75	85-145	605-645	
								Number of Trees								
	Living	105	64	116	123	105	89	92	102	83	58	114	70	76	64	1,261
Condition of Tree	Killed 45 or prior	51	5	50	40	51	31	30	24	125	13	0	12	8	0	440
	Killed 46	103	24	125	98	108	94	74	71	90	41	1	58	15	7	909
	Killed 47	1	2	3	1	0	0	2	3	5	2	0	1	2	0	22
	Total	260	95	294	262	264	214	198	200	303	114	115	141	101	71	2,632
	Reduction in Loss %	99.0	91.6	97.6	98.9	100	100	97.3	95.8	94.4	95.1	#	98.2	86.7	100	97.6
	Foliage Injury	Severe	Medium	None	Severe	Severe	Light	None	None	None	None	None	Medium	None	None	

Practically no loss in 1946.

using Formula C at the rate of 2 lbs. of DDT per acre, there were no trees killed in 1947 compared to 94 killed in 1946 or a reduction of 100% in loss. In this latter test of 2 lbs. of DDT per acre, there was light foliage injury even though this was a water emulsion. The only possible explanation for this is that the xylene, used to dissolve the DDT, caused the damage. J. M. Miller found similar injury in heavy application of this formula at Placerville. In all of the above tests with the hand-pack rigs, 25 percent of the sprayed areas were sampled for less reduction. In the case of the turbine, approximately 15 per cent of the area was sampled.

TREES KILLED BY THE WEEVIL ON UNSPRAYED CHECK AREAS

The check unsprayed area was located just to the west of the series of rows which were treated by spraying in Compartment P-55-37. Each tenth row from 401 to 491 were used as samples. These totaled approximately 50 acres altogether. The number of trees killed prior to 1946, those killed in 1946, and those killed in 1947 are presented in Table 10. From this it may be noted that there were 661 trees killed on these plots in 1946 and 723 trees killed in 1947, or an average slight increase in the 1947 loss. If it can be assumed that the loss on the treated areas would have followed this same pattern, had they not been treated, then very satisfactory control was achieved in the spray program.

Table 10.--Trees Killed by Reproduction Weevil on Check Sample Plots

Burney Springs Field
Compartment P-55-37

Sample Row	401	411	421	431	441	451	461	471	481	491	All Check Rows
	(Number of Trees)										
Living	160	175	190	240	97	224	88	164	154	60	1,552
Killed 1945 or prior	51	70	35	48	58	40	63	45	90	85	585
Killed 1946	86	35	78	62	33	87	70	64	57	89	661
Killed 1947	90	55	62	82	83	44	96	52	48	111	723
Total	387	335	365	432	271	395	317	325	349	345	3,521

RELATIVE EFFICIENCY OF THE DIFFERENT METHODS OF SPRAYING

In a comparison of the three methods of spray application used in this experimental control job, it was very apparent that the airplane application was superior to either the turbine or hand machines, under the conditions of the experiment. From the standpoint of cost, the airplane was slightly superior to the turbine, and about three times more efficient than the hand rigs. The average cost per acre for material and labor for the airplane job was $1.11, the estimated cost by the turbine was about $1.66, and by the hand method about $3.33, based on labor and material cost prevailing during the early summer of 1947 (Table 11).

The airplane had a superior advantage over the turbine in the treatment of these heavy brushfields in that the spray could be applied in any direction desired. The location of existing roads and the direction of the prevailing winds greatly limited the use of the turbine in this particular experiment. It was also found that the distribution of the

Table 11.--Relative Cost of Applying DDT by Three Different Methods

(Cost per Acre)

Method	Labor	Materials	Total
Airplane	$0.36	$.75	$1.11
Turbine	.80 est.*	.86	1.66
Hand Back-pack	2.58	.75	3.33

(Based on the rate of application of 1 lb. of DDT in xylene and diesel oil per acre. Formula A was used for the airplane and hand back-pack sprayers, and Formula D was used in the Turbine.)

*Note: The figure for labor on the turbine is based upon favorable weather conditions prevailing during the time of application. This figure is a very rough estimate based on the experience with the machine during the period when it was operated. The other estimates are considered to be fairly accurate.

spray was much more uniform when applied from the plane than from the turbine. Another advantage of the airplane is that a large area can be covered with one unit in a relatively short period of time. It is estimated that it would be possible to spray 1,000 acres per day with one plane if the airport was within ten miles of the field to be sprayed. It is estimated that the maximum area which could be treated with the turbine in brushfield plantations would be about 200 acres per day. This is assuming optimum road conditions and favorable wind conditions. It was found that the average number of acres which could be covered by one man in one day with the back-pack sprayer was 3.1. It was also found that the work of spraying trees in heavy brush rows was exceedingly difficult because of the hose and carrier strap tangling with the brush. Because of the excessive cost and difficulty of manipulation it is felt that the hand work should be restricted or eliminated in the control of the reproduction weevil.

SUMMARY AND CONCLUSIONS

An experimental control project was undertaken against the pine reproduction weevil in June 1947 by the U. S. Forest Service with the technical help of the Berkeley Forest Insect Laboratory. This test was carried out in two brushfield plantings on the Shasta and Lassen National Forests of California, where this insect was causing very serious damage to planted pines, in an effort to control this insect. Concentrated formulae of DDT in diesel oil, kerosene, and water emulsions were applied at the rate of one and two lbs. of DDT per acre by means of airplane, turbine blower, and hand back-pack sprayers. The following control results were achieved:

1. Populations of adult weevils were reduced from a level of 30 and 50 per tree in the Shasta and Burney Springs fields, respectively, to 1 and 2 weevils per tree within a period of two weeks after spraying. This low level of population was maintained throughout the rest of the season of activity of the weevil. During this same period, the population level of weevils in the check unsprayed area in the Burney Springs field remained at a level of about 50 weevil per tree until late in August when it dropped to a level of about 20.

2. Significant residual effect of the DDT was apparent for a period of about two months following the spray application in both fields.

3. There appeared to be very little difference in the effectiveness of the different formulae tested--all formulae gave satisfactory control resulting in a reduction of loss of more than 90 percent in both fields.

4. There appeared to be very little difference in the effectiveness of the spray applied by the different machines. What slight superiority there appeared to be was in the following order of effectiveness: hand machine, first; turbine blower, second; and airplane, third.

5. From the standpoint of efficiency, the airplane rated first, the turbine second, and the hand machine third. The average cost per

acre of treating at the rate of 1 lb. of DDT per acre was: for the airplane $1.11; for the turbine $1.66; and for the hand machines $3.33.

6. While the loss reduction was in excess of 90 percent on the sprayed areas, the check unsprayed area of the Burney Springs field showed losses in 1947 slightly greater than for 1946.